White Paper — 21st Century Technology Series

Off-Site Construction

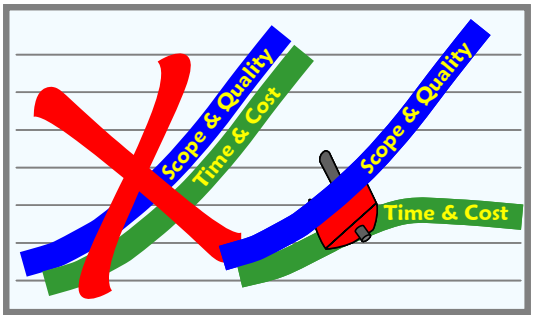
While modernist architects and New Urbanist planners are rediscovering the advantages of modular construction processes, in many sectors that commission construction this technology is ignored or even despised. Frankly, we were at a loss to understand why the process used to build jet planes and luxury automobiles, not to mention power and petrochemical plants, should be so cavalierly dismissed when discussing the building of, for example, schools. After some investigation, we discovered that there is a wealth of misapprehension circulating about the advantages and disadvantages of modular construction. This paper attempts to clarify the advantages of off-site construction.

What is Modular or Off-Site Construction?

Modular or off-site construction refers to the practice of designing a large structure, such as a school or an airplane, so that it can be assembled on site using subassemblies constructed under controlled factory conditions. It is merely an extension to the field of construction of the lessons learned over the past century in manufacturing facilities of all kinds. Making it work well requires embracing the whole gamut of 21st century technologies that are transforming the manufactured goods market from one of mass production to one of mass customization: parametric design tools, modeling and simulation, integrated supply chain management, on-line management information and project management tools, etc.

Why is Modular or Off-Site Construction so Advantageous?

Properly executed, off-site construction does the same thing for construction that modular manufacturing has done for product manufacturing: it increases product quality and scope while decreasing production costs and time. The construction industry is one of the last to buy into the paradigm that increases in scope and quality are inextricably yoked to increases in time and cost — in virtually all other industries, it is understood that rigorous process engineering continually drives down costs and time, while product features, quality and responsiveness to customer demands continue to improve, because the 21st century market will stand for no less.



The best quality off-site construction process begins with parametric design. Multi-dimensional parametric models allow buyer and architect to simulate the finished product down to the smallest detail. The parametric software tests the model against design objectives, which can range from meeting building codes, capacity standards, and cost or site constraints, to providing space that suits different learning and teaching modalities, to meeting daylighting or air quality goals. The building can be situated in the terrain, allowing simulation of the impact on the building and its occupants of sun, wind and weather patterns as well as traffic flows during construction and after occupancy. This model not only becomes the statement of work, so that there is no disconnect between what the buyer envisioned and the built structure, but also the permanent planning tool for future building use and/or expansion, allowing effortless “what-ifs” and future change management.

The least understood advantage of off-site construction is the ability to incorporate increased quality control into the construction process. When building subassemblies are constructed in the controlled environment of a factory setting, the builder can take advantage of line manufacturing efficiencies. Not only are cuts and joins more precise because they can be guided by jigs, but wiring, plumbing, HVAC and data can be preinstalled and tested in the factory. Material degradation by weather is eliminated and scrap and waste drastically reduced. Applying production management technologies means that scheduling and costs become pre-

dictable and stable. Finally, mass customization is vastly simplified so that the end product can actually look custom-designed to meet local aesthetic or cultural requirements at no additional cost.

How Does Modular or Off-Site Construction Drive Costs Down?

Efficient use of parametric modeling technologies can drastically reduce "soft" costs of construction. While on-site construction costing formulas today allow 30 to 40 percent for design and engineering costs, Boeing maintains soft costs for designing and engineering jumbo jets under 22 percent! Parametric modeling allows simple re-use of repetitive elements, and the customer should not have to pay for the draftsman to drag a standard restroom onto a model at the same rate as he pays for a unique design. Moreover, with the ability to have the customer walk through the simulated structure before the first nail is ordered, change orders are virtually eliminated.

On the "hard" side, off-site construction saves money in terms of both materials and time. It exploits the ability to schedule in parallel: site prep and building construction can overlap because the building sub-assemblies are being built off-site, and multiple similar assemblies can be built in parallel. Manufacturing costs are reduced as the builder can implement assembly line style efficiencies in construction as well as in managing the supply chain. Worker safety and comfort is improved as construction takes place in a controlled environment equipped with ergonomic workstations, and consequently productivity improves. Hard costs for off-site construction can be up to 30 percent less than for an equivalent structure built on-site. When combined with the reduction in soft costs, these savings add up to being able to get 110 percent of the quality for 70 percent of the cost of the equivalent on-site-built structure.

Examples

The Pierson College Dormitory on the campus of Yale University has become the poster-child for quality modular construction in educational settings and has been cited *in Engineering News Record*, *School Planning and Management* and many other publications. The 27,800 square foot dormitory was erected on-site in five days over spring break, after an off-site construction cycle of just 188 days. Modules and the cranes to lift them in place were brought into the fully enclosed quadrangle through one narrow alleyway, leaving the rest of the quadrangle undisturbed. The 34 modules were designed to be architecturally consistent with 300-year-old neighboring campus buildings, with custom brickwork, half-octagonal staircases, windows with concrete lintels, hardwood floors, solid core wood doors, quarry tile and many other features.

This 6-module addition to a California bed-and-breakfast integrates seamlessly with the existing traditional stucco building and contains architectural features such as the solid timber post and beam roof trellis, terra cotta curved roofing, arched entrances, vaulted ceilings, solid timber exposed ceiling beams, solid hardwood and European tiled flooring, extensive millwork, and tiled counters. It, too, was erected on site in five days, minimizing disruption for guests.